Applications of RS, GPS and GIS to Forest Management in China

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Abstract Applications of remote sensing (RS), global positioning system (GPS), geographic information system (GIS) and combination of three-S techniques in the forest management are introduced. It indicates that, with the quickly improvement of the computer technique, the three-S system will become a very important part of the forestry management system.

Key words Geographic Information System, Remote Sensing, Global Positioning System, Digital Terrain Model

Forest is an important renewable resource which is composed of all kinds of plants. It has the characters of long growth period and complex land distribution. So it has special rules of dynamic change. Forest cannot be substituted by other resources in the economic construction and environmental protection. So it is important to establish a good pattern of forest resource management. In order to realize this goal, first the dynamic change of forest resource must be monitored and predicted, then on this base the forest resource management pattern of sustainable development should be established. So it can elaborate economic, ecological and social benefits of forest resource well.

Using geographic information system (GIS), remote sensing (RS) and global positioning system (GPS), usually called Three-S System, we can set up an information administrative system of forest resource. Three-S system can quickly provide information storage, searching and analysis. It can be used in comparison and evaluation of various plans of forest management to realize the scientific management of forest resource.

Application of RS in forest management

Remote sensing is a new technique that bases on the aerial photography and developed in the early days of 1960's (Xu 1998). According to the mechanism that the object responds to the electromagnetic spectrum differently, terrestrial objects can be distinguished by using remote sensor from the sky. That is, the remote sensor carried by aircraft such as plane, dirigible or satellite can collect data of the ground, and with this information we can distinguish terrestrial objects by the procedure of recording, sending, analysis and classification (Sun *et al* 1997). With remote sensing technique, we can capture data of large area and quickly collect information in very short time with little restriction.

The basic function of remote sensing in the management of forest resource is to acquire the terrestrial information. By manual or computer identification we can extract all kinds of environment information from the aerial photography, satellite photography and multispectral electronic scanning photography which acquired by the remote sensing technique, and use these information to build digital terrain model (DTM). With the DTM technique, we can use the stereogram to describe the plane and spatial distribution and statue of terrestrial objects vividly. In the DTM stereogram we can outguess the terrain and each cross section. Remote sensing is widely used in the calculation of the cubic meter of earth in excavation, road planning, making slope map, analyzing landform and so on. With computer, users can use DTM to make stereogram and planimetric map from any viewing point and angle as long as the computer resource is allowed. Simultaneously, combined with GIS, it can complete the inquiry of the attribute character of anywhere in the DTM.

It is feasible to use remote sensing technique for making forestry maps, including forest plane map, forest striograph map, forest map, forest site type map and forest soil map, etc.. For making these maps, the aerial photography, satellite photography, sometimes multispectral photography and radar photography are used. Remote sensing technique may be adopted to conduct aerial visual survey, forest divi-

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sion and mapping, forest resource exploration and sampling survey. On forest resource management, Its uses include forest resource monitoring, forest fire monitoring, pest monitoring, forest ecological environment monitoring and constructions of forest land utilizing map and site type map.

Application of GPS in forest management

GPS is an aeronavigation system based on radio positioning system, navigation system and timing system (Li 1998). Regarding the distance as basic observation unit, GPS can calculate the receptor's position by measuring the fake distance of several satellites at the same time (Yao 2000). Because this measurement can be finished in very short time, it is possible to realize the dynamic measurement. GPS technique originates from martial demand and has got rapid development in recent years. Presently, it is widely applied in the forest survey. Application of GPS in forest management maintains in the following aspects: (1) GPS has a widely application in field measurement. A new subject—GPS global geodesy has formulated. As a result of adopting the differential technique, the precision of DGPS (differential GPS) can reach one centimeter, which is enough to meet the requirement of forest management. (2) By using GPS, the forest surveyor can locate his azimuth exactly and on time during survey of forest resource. (3) With assistance of GIS, the firemen can report the exact position and height of forest fire to the commander in time. (4) In forest fertilization, according to the soil data, position fertilization can be realized by using the appropriate software making fertilization equipment and GPS work at the same time.

Application of GIS in forest management

GIS, as a new technique developed with the computer technique since 1960's (Lu *et al* 1998), is a spatial information system that comprises four basic elements of computer hardware, computer software, data and user. By capturing, storing, checking, manipulating and analyzing the terrain information concerned with spatial and geographic distribution, it can export all kinds of data and graphs, and provide a series of assistant facilities and plan for the decision-maker. GPS is a new marginal science that includes computer science, geography, topography, environment science, geoscience, spacing science, information science and management science. With combination of spatial distribution and computer techniques, by a series of spatial operation and analysis, it can provide useful information for enterprise operation, civic construction and country economic development. As tools of spatial management and analysis, GIS has important function in forest management. Its applications are mainly as follows:

Dossier administration of forest resource

The dossier administration of forest resource using GIS is quite different from the ordinary database system. It combines the graphs and database organically to realize the computer management of forest resource dossiers. It has two superiorities: Firstly, on data inquiry and export, it can export not only statistic data and chart like ordinary database system, but also the relative spatial data with graphs. Using this method of combined graphs with attributes, we can know the forest resource status momentarily and process our statistic and analysis, and the scientific management of forest resource can be realized. Secondly, data can be updated promptly. In GIS, the data of attribution database and point of land map can update dynamically. That means when the attribution of the terrain objects changes, the state of the map point will be automatism update.

Monitoring dynamic change of forest resource

The ordinary management system can only reflect the quantity changes of the forest resource. However, GIS have its own spatial data and spatial analysis function. Using the data provided by the RS and GPS, we can use correlation analysis method to study the spatial distribution rules of forest resource and its influence to the development of the city in the future. This can provide countermeasures for the decision-makers to adjust the development strategy, and accelerate the forest resource development toward stabilization and exuberant. To predict the disaster, firstly, we can build all kinds of prediction models in GIS, by inputting the data collected by RS and GPS simultaneously. Secondly, we can build a disaster prevention system by inputting distribution status of the rescuers and equipment in GIS, and it can provide the technique and methods for the leading section to arrange the rescuers and equipment. For instance, when fire burst out, we can use GIS to select the best plan to put down the fire, and assemble the rescuers and equipment immediately. Thirdly, we can use GIS to calculate the suffering area and the losing quickly, and make the rescue and restoration plan.

Silvicultural plan and design

There are several applications of GIS on silvicultural plan and design, such as planting design, cultivation of fast growing and high yield forests, improvement of poor forests, regeneration design of thinning, and the survey and planning of seed orchard, seed stand and nursery. For example, using GIS, we can make forest site type maps and tables,

matching trees with sites.

Assistant decision of forestry production

GIS can provide various plans of forestry production for comparing and analyzing (Zhang Hong 1999), as the base of scientific decision-making. GIS can do engineering assistant design of geographic information. But GIS is different with AUTOCAD. GIS can do not only the map design of special data, but also argument design, that are analysis and calculation of engineering. For example, we can use GIS to do the plan and design of road net on forestry region, including not only the roads distribution, but also the calculation of engineering amount and the budget of engineering investment. GIS can find the optimal distribution plan of road net according to given conditions by calculation and analysis. And it can fix on the corresponding special map. On the base it can provide the design result and report data, such s volume of earthwork, bridge and culvert.

In addition, GIS has many other uses in forest management. It contains great technique potential for us to develop.

Combined use of three-S techniques in forest management

As tools of spatial information processing, each of the three-S techniques has its own characters and can fulfill its own function separately. The problems they can solve are relative, but each of them has their own advantage and deficiency. GIS has strong function on inquiry, analysis and synthetic processing, but it is very difficult for GIS to get the data. RS can collect the information of large area effectively, but limited by the band of spectrum, and the precision of its data orientation and classification function is lower. GPS can provide the target's position quickly, and this has special significance for spatial data, but it can't provide the attribute data of the target. So the combination and integration of the three has become a trend of space science and spatial information system. As a result of the coalescence of the mapping, remote sensing, cartography, orientation and management, the three-S system will become a useful tool to spatial analyze and decision.

Modern forest management system is an organic synthetics comprising of multi-system, multi-layer, multi-function and multi-space. Each portion of it not only mutually promotion, but also mutually restrict and conflict. This relationship varies with the temporal change, so it is difficult to monitor and predict forest resource only depending on any one system. So it needs three systems to combine usually in the practice. In the forest management, we get basic information with RS, decide position and navigation with GPS, analyze and process with GIS. By the way, all kinds of data, graph and decision can be gained. With the rapid development of computer technology, the united three-S system based on the multimedia and network techniques must amplify more affects in forest management (Yue 1999).

Three-S may has potential applications in four aspects. Firstly, Three-S can change the operation pattern of traditional forest survey, shorting period and decreasing cost of operation, because it can give us 3 dimensional information. Secondly, It can improve the events monitoring of forest fire and pest. We have done experiments of using airplane, satellite and field data at the same time in China. It guarantees the monitoring of disaster events all the time. Thirdly, Three-S can construct various forestry tables quickly, with no influence of time and region. With geoscience code photography, it can directly output various maps including topographic map in short time and has high precision. Finally, the Three-S is favorable to set up modern national monitoring system of forest resource, which can dynamically monitor the special information of forest resource, including not only the macro change of forest resource on national or regional scale, but also local change on county scale (Dai 1997). With respect to monitoring contents, Three-S can monitor not only the quantity of forest resource, but also the dynamic change of ecological environmental information.

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